HABITAT SELECTION BY THE MARBLED TEAL *MARMARONETTA ANGUSTIROSTRIS*, FERRUGINOUS DUCK *AYTHYA NYROCA* AND OTHER DUCKS IN THE GÖKSU DELTA, TURKEY, IN SUMMER

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INTRODUCTION

The Göksu Delta, southern Turkey, is a Ramsar Site (Frazier, 1996), a Specially Protected Area and an Important Bird Area (Magnin & Yarar, 1997) and is extremely important for breeding and wintering waterfowl (DHKD, 1992). In particular, it supports internationally important breeding populations of Marbled Teal *Marmaronetta angustirostris* (*c.* 50 pairs) and Ferruginous Duck *Aythya nyroca* (*c.* 30 pairs) (Schepers *et al.*, 1989; Green, 1993). Mallard *Anas platyrhynchos* (*c.* 50 pairs) also breed there, and Garganey *A. querquedula* use the delta during post-breeding passage (Schepers *et al.*, 1989; DHKD, 1992).

In this study, I compare the habitat use of these four species in the Göksu Delta in July-August at three spatial scales: the use of distinct wetlands affected in different ways by anthropogenic changes, the selection of different biotopes within those wetlands and the selection of different microhabitats within those biotopes. The Marbled Teal and Ferruginous Duck are globally threatened species (Collar *et al.*, 1994; Green, 1996b) undergoing declines in the Mediterranean region largely attributed to loss of breeding habitat. Their habitat requirements are almost unknown and need to be identified to enable their conservation (Green, 1993; Tucker & Heath, 1994; Heredia *et al.*, 1996; Callaghan, in press). The Garganey is considered Vulnerable in Europe and is undergoing widespread population decline which may be partly caused by habitat loss at passage sites (Tucker & Heath, 1994). Garganey habitat use has been studied at breeding sites (Pöysä, 1983a,b; Nudds *et al.*, 1994), but not during post-breeding migration. Habitat selection by Mallards has been extensively studied in other parts of its range (e.g. Godin & Joyner, 1981; Talent *et al.*, 1982; Rotella & Ratti, 1992; Kaminski *et al.*, 1993; Nummi *et al.*, 1994), but in the Mediterranean region only its nesting ecology has been studied (Amat 1982, 1985).

I test for differences in habitat selection between broods and mature Marbled Teal. I consider whether the rarity and restricted distribution of Marbled Teal and Ferruginous Duck at a macroecological scale (in the Mediterranean region) is reflected by specialized habitat use or inability to exploit artificial wetlands at a

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microecological scale (in the Göksu Delta). I discuss the implications of this study for the conservation of Marbled Teal, Ferruginous Duck, Garganey and the Göksu Delta.

STUDY AREA

The major wetlands in the Göksu Delta (total area 15,000 ha) include the Göksu river, the large lakes of Akgöl and Paradeniz, a network of drainage canals in the surrounding agricultural area and oxbow lakes (Fig. 1). In recent decades, the hydrology of the delta has been transformed by agricultural development (DHKD, 1992; ter Haar & Heunks, 1992). Akgöl used to be a semi-permanent, hyper-saline lake with no connection to the sea. Drainage water from fields to the north of the lake now runs into Akgöl, which has been connected with Paradeniz lagoon, the latter being connected to the sea (Fig. 1). As a result, Akgöl is now a permanent, densely vegetated, fresh to brackish eutrophic lake with its water levels peaking in summer. Paradeniz and the smaller Kugu Gölü are open, saline lagoons with very little vegetation. The main oxbow to the east of the river receives drainage water from surrounding agricultural fields and is permanent, brackish and cut off from the sea by a sandbar (Fig. 1). Fishing and cattle grazing occur on a small scale throughout the delta causing some disturbance to waterbirds, whilst hunting is forbidden (DHKD, 1992).

This study was conducted when Mallard had completed breeding and large numbers of post-breeders from other areas were present. Marbled Teal and Ferruginous Duck were at the end of their breeding seasons. The Marbled Teal is a particularly late breeder (Green, 1998a), and many Marbled Teal broods had not yet fledged. Garganey begin to arrive in the delta in early July and their numbers peak at 3,000-5,000 in late August (van den Berk & van der Winden, unpubl.)

METHODS

SURVEY TECHNIQUES

Fieldwork was conducted from 10 July to 6 August 1995 inclusive. Each of the following wetlands was surveyed three times for all Anatidae: Algöl and its immediate surroundings, Paradeniz lagoon, Kugu Gölü, the drainage canals to the north of Akgöl and the main oxbow to the east of the river (Fig. 1).

Lake Akgöl was surveyed by canoe, whereas the areas around the lake's edge (pools, marshes, drainage canals) and other wetlands were surveyed from the bank. Fieldwork was mainly conducted from first light (06 45 h local time) to 14 00 h, although the whole daylight period was covered to some extent. Three complete surveys of all areas of Akgöl accessible by canoe were conducted over the periods 18-23 July, 24-28 July and 30 July - 5 August, in such a way that the interval between surveys of the same part of the lake was at least four days.

Details of all ducks observed with a telescope or binoculars were recorded on a dictaphone. The behaviour of each individual at the time of initial observation was recorded as feeding, or other. Birds observed feeding were assigned to six

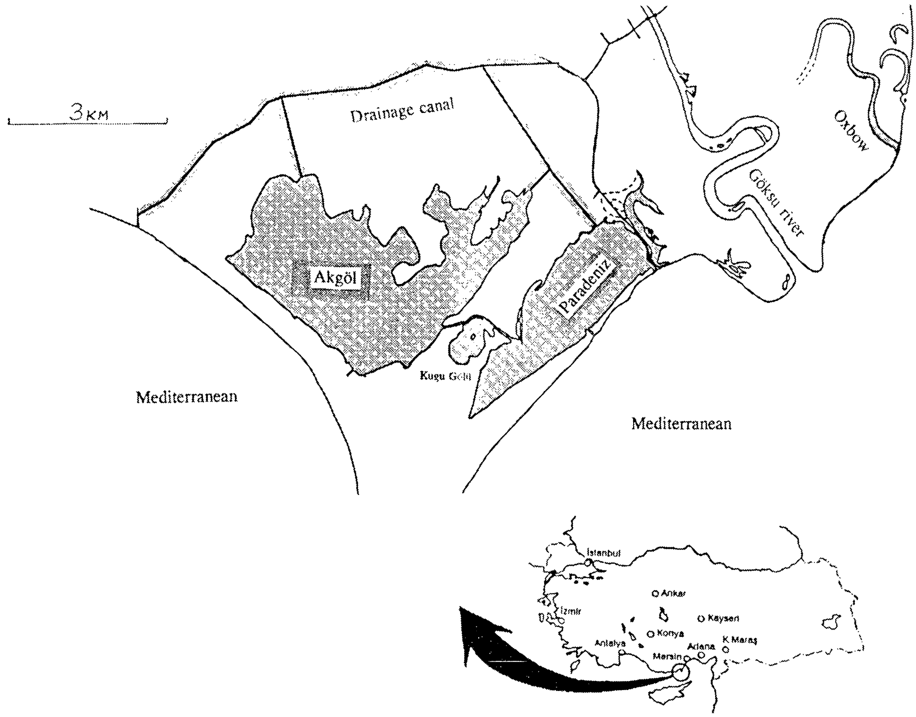


Figure 1. — The location of the Göksu delta in Turkey, and the wetlands included in this study (stippled).

methods: dive, up-end, neck dip (part or all of neck submerged), head dip (eye submerged), bill dip (part or all of bill submerged) or gleaning (bill held in the plane of the water surface, straining items from the water surface).

For each individual Mallard, Marbled Teal and Ferruginous Duck, the following details of its position prior to any response to the presence of the observer were recorded, estimating distances visually in metres: "habitat zone" (at Akgöl, see below), distance to nearest conspecific, distance to nearest emergent vegetation, species of emergent, distance to wetland fringe, presence or absence of submerged macrophytes at the surface layer. At Akgöl, the lake fringe was considered to be the inner edge of the dense emergent fringe of variable thickness that surrounds the lake (Fig. 2). Conspecifics seen within 10 m of each other were considered members of one flock. Observations of birds in flight and suspected repeated observations of the same individual on the same day were discarded. Garganey were observed in large flocks of up to several hundred birds, and it was impractical to collect data for each individual. Instead, the above details were recorded from a random sample of feeding individuals from each flock.

HABITAT CHARACTERISTICS

For all wetlands, estimates of area, width, percentage of wetland covered with emergent vegetation, percentage of wetland with submerged or floating vascular

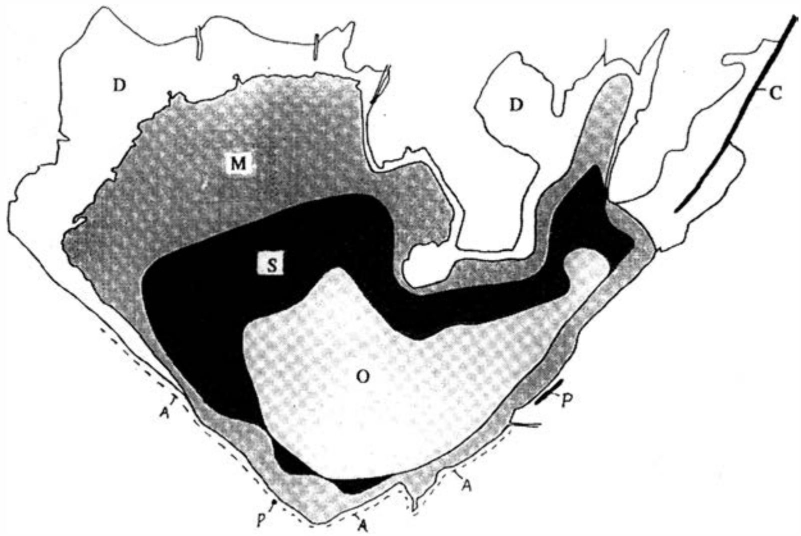


Figure 2. — Different habitat zones in Akgöl. D = dense emergent fringe, M = mixed emergent zone, S = *Scirpus*-only zone, O = open water zone, C = canal zone, A = marsh zone, P = pools zone.

plants at the surface and percentage of wetland border with emergent vegetation were calculated using visual estimates, a 1:20,000 aerial photograph of the delta (taken on 25.12.93) and published information (DHKD, 1992).

The main Lake Akgöl was divided into four biotopes representing different successional stages (Fig. 2). The "dense emergent fringe" was an impenetrable reedbed dominated by *Phragmites australis* and *Typha* sp.. It could not he surveyed owing to its inaccessibility, but duck flight paths suggested that it was not important for Anatidae during the current study. The "mixed emergent zone" contained a mixture of emergent vegetation, with abundant *Phragmites australis*, *Typha* sp. and *Scirpus* (= *Schoenoplectus*) *litoralis*. This zone was relatively shallow (mean depth 43 cm) with a thick silt layer and dense beds of *Potamogeton pectinatus*. *S. litoralis* was the only emergent vegetation in the "*Scirpus*-only zone". The abundance of *P. pectinatus* was intermediate in this area, with some dense beds filling the surface layer. The water depth (mean 55 cm) and thickness of the silt layer were intermediate. Birds were considered to be in the *Scirpus*-only zone when they were within a polygon around the outermost patches of *S. litoralis* in which no other emergents were included. The "open water zone" was the innermost, deepest (up to 1 m) part of the lake with no emergent vegetation. It contained a thin silt layer and *P. pectinatus* was thinly distributed, rarely reaching the lake surface. The mixed emergent and *Scirpus*-only zones were much wider in the north and west parts of Akgöl, owing to the siltation caused by canals draining into that part of the lake (Fig. 2).

Three other biotopes were identified around the periphery of the lake (Fig. 2). The "canal zone" was a drainage canal entering the north-eastern corner of Akgöl. This canal was 15-20 m wide, bordered by *Typha* sp. and *Phragmites australis* with patches of *Potamogeton nodosus* on the water surface. The "marsh zone" was a narrow band of shallow, seasonally flooded marsh bordering the dense emergent fringe alongside the southern edge of the lake. This was dominated by *Scirpus maritimus*, a short variety of *Phragmites australis*, *Salicornia europea* and *Arthrocnemum* sp. with occasional patches of *Tamarix smyrnensis*. The "pools zone" consisted of two open areas within this saltmarsh habitat. There was a small lagoon of 2.8 ha along the eastern lake shore. Half this lagoon was open water with the rest containing *Scirpus maritimus*, a short variety of *P. australis*, *Salicornia europea* and *Arthrocnemum* sp. There was also a pool of 0.08 ha along the south shore. The oxbow lake (Fig. 1) was fringed mainly by *Phragmites australis* and *Typha* with some patches of *Scirpus litoralis*. *Potamogeton pectinatus* was present at a lower density than in Akgöl. The western shore was flanked by ricefields.

Chemical measurements were taken *in situ* from a depth of 10 cm at various points in the delta. Electrical conductivity (corrected for temperature variation) was measured with a HI 8733 conductivity meter, and pH with a HI 1290 pH meter.

STATISTICAL ANALYSES

Unless otherwise stated, each flock of ducks was considered as one independent observation in statistical analyses, pooling data from three censuses. Selection of different biotopes at Akgöl was analysed following Neu *et al.* (1974), using Bonferoni Normal Statistics to calculate confidence intervals for the relative importance of each habitat. χ^2 tests were used to compare the observed distribution of duck flocks with that expected from the area of each habitat. Although there were some cases in which expected values were below 1, the results were reliable because the average (over all habitats) expected value was well over 6 and the P values were extremely small (Roscoe & Byars, 1971; Neu *et al.*, 1974). The analysis of zone use by Marbled Teal broods, which had a small sample size, was an exception. However, the very low P value obtained in this test suggests the distribution of broods was non-random.

RESULTS

SELECTION OF WETLANDS WITHIN THE DELTA

All ducks were highly concentrated at wetlands (Akgöl and the oxbow) with intermediate conductivity (equivalent to brackish), and large amounts of emergent and submerged vegetation (Table I). In contrast, ducks were practically absent from saline wetlands lacking vegetation (Paradeniz and Kugu Gölü). Although drainage canals offered some characteristics apparently favoured by ducks (vegetation cover, low conductivity), they were totally avoided with the exception of points where canals enter Akgöl (Table I).

SELECTION OF BIOTOPES AT AKGÖL

Marbled Teal, Ferruginous Duck and Mallard were non-randomly distributed between the different biotopes available at Akgöl (Table II). Despite its large size,

TABLE I

Use (number of birds ha^{-1}) of various wetlands in the Göksu Delta by Anatidae, 10 July-6 August 1995.

Site	Maran	Aytny	Anapl	Anaqu	Other	Area	Width	%EB	%EA	%SA	Cdy	pH
Akgöl complex[1]	0.10	0.09	0.52	0.97	0.06	1,400	3,000	100	60	30	9.98	9.26
Oxbow	0.46	0	0	0	0	24	140	95	10	20	6.22	8.11
Kuğu Gölü	0	0	0.04	0	0	50	500	0	0	0	40.9	8.62
Paradeniz	0	0	0	0	0	390	1,300	1	0	0	54.7	8.22
Drainage canals	0	0	0	0	0	17	15	60	25	20	0.39	8.21

[1] Includes the lake itself plus marshes and stretches of canals within 200 m of the lake border. Maran: Marbled Teal. Aytny: Ferruginous Duck. Anapl: Mallard. Anaqu: Garganey. Other: other Anatidae species combined (Greylag Goose *Anser anser,* Ruddy Shelduck *Tadorna ferruginea,* Red-crested Pochard *Netta rufina* and Common Pochard *Aythya ferina*). Figures calculated from the maximum counts of each species at each wetland. Area: total area of wetland in ha. Width: maximum width of wetland (m). %EB: estimated percentage of wetland edge which is bordered with emergent vegetation. %EA: estimated percentage of total area of wetland that is occupied by emergent vegetation. %SA: estimated percentage of water area which has submerged or floating vegetation (excluding algae) visible at the water surface. Cdy: average conductivity, mS (note 10 mS is approximately equivalent to a salinity of 7.7 ppt). pH: average pH.

no ducks were recorded in the open water zone. Within the lake itself, whilst Mallard were almost confined to the mixed zone, both Marbled Teal and Ferruginous Duck made extensive use of both the mixed and the *Scirpus*-only zones (Table II). The relative use of these two zones differed significantly between Marbled Teal and Mallard ($\chi^2 = 89.2$, 1 *df*, $P < 0.0001$) and Ferruginous Duck and Mallard ($\chi^2 = 46.8$, $P < 0.0001$), but not between Marbled Teal and Ferruginous Duck ($\chi^2 = 2.81$, *ns*). Marbled Teal and Mallard also made use of small peripheral biotopes (canal, pools and marsh) (Table II). The habitat use of Garganey was not

TABLE II

Number of flocks and individuals (in parentheses) of ducks recorded in different habitat zones at Akgöl.

Zone	Area (ha)	PA	Anapl		Maran		Brood		Aytny	
Mixed	566	0.602	289	(1 160)	48	(103)	2	(9)	45	(134)
Scirpus	345	0.367	2	(5)	23	(31)	1	(12)	11	(27)
Open	316	–	0	–	0	–	0	–	0	–
Canal	3	0.002	0	–	6	(8)	6	(20)	0	–
Pools	3	0.006	7	(16)	10	(22)	0	–	1	(3)
Marsh	10	0.023	5	(10)	1	(1)	0	–	0	–
Total	1 243	1.0	303	(1 191)	88	(165)	9	(41)	57	(164)

Anapl = Mallard. Maran = Marbled Teal (excluding broods). Brood = Marbled Teal broods (including ducklings and accompanying adults). Aytny = Ferruginous Duck. PA = proportion of total area surveyed (excluding open zone). See Fig. 2 for the location of each zone.

analysed statistically, as observations were not divided into flocks. However, 97 % of individuals (N = 885) were recorded in the mixed zone, and the remaining 3 % in the *Scirpus*-only zone.

The distribution of feeding ducks was similar to that of flocks. All feeding Garganey (N = 76) were in the mixed zone, whereas 96.4 % of Mallard (N = 111) were in the mixed zone, 2.7 % in the *Scirpus*-only zone and 0.9 % in the pools. Some 92.7 % of feeding Ferruginous Duck (N = 41) were in the mixed zone and 7.3 % in the *Scirpus*-only zone, whereas 63.0 % of feeding Marbled Teal (N = 27) were in the mixed zone, 29.6 % in the *Scirpus*-only zone and 7.4 % in the pools.

The relative use of different habitat zones by flocks was non-random for Mallard, Marbled Teal and Ferruginous Duck (Table III). The relative importance of each habitat type is given by ranking the selection indices in Table III (e.g. pools > mixed > marsh > *Scirpus* > canal for Mallard). When there is no overlap between the confidence intervals on the selection indices in Table III for two habitats, the use of these habitats was significantly different (e.g. for Mallard the mixed zone was preferred significantly to the marsh and *Scirpus* zones, and the pools zone was preferred significantly to the *Scirpus* zone).

Comparing confidence intervals of selection indices between species (Table III, excluding broods) reveals the following statistically significant differences: the mixed zone was more important and the *Scirpus* zone less important to Mallards than to the other two species; the mixed zone was more important to Ferruginous Duck than to Marbled Teal; the marsh zone was more important to Mallard than to Ferruginous Duck; the canal zone was more important to Marbled Teal than to the other two species. The canal zone was even more important for Marbled Teal broods than for mature Marbled Teal (Table III). Groups of fully grown Marbled Teal observed in this zone appeared to be either breeding adults or newly fledged juveniles. Pools were more important for mature Marbled Teal than for broods (Table III).

SELECTION OF MICROHABITATS AT AKGÖL

Within Akgöl, there were significant differences between duck species in the association of flocks with different emergents (Fig. 3a). Marbled Teal were mainly associated with *S. litoralis*, and Mallards with *Typha* sp. Ferruginous Duck had no strong associations with any emergent species (Fig. 3a). Feeding Mallard, Marbled Teal and Ferruginous Duck were associated with emergents in a similar way to flocks (Fig. 3b). Feeding Garganey showed the strongest association with *Typha* and the weakest association with other species (Fig. 3b).

There were significant differences in the distances to emergent vegetation between flocks of Mallard (0-50 m; median = 1 m), Marbled Teal (0-30 m; median = 5 m) and Ferruginous Duck (0-150 m; median = 5 m) (Fig. 4a). Pairwise (Mann-Whitney) tests showed that there were significant differences between Mallard and Ferruginous Duck ($P < 0.001$) and Mallard and Marbled Teal ($P < 0.03$) but not between Ferruginous Duck and Marbled Teal ($P > 0.05$).

Feeding birds tended to be farther away from emergent vegetation than inactive birds, which often roosted inside patches of emergents. Hence distances to nearest emergents for feeding birds were generally longer than those for all flocks (Fig. 4b). There were significant differences in the distance to emergents between feeding Mallard (0-30 m; median = 5 m), Marbled Teal (0-200 m; median

TABLE III

Selection of habitat zones by ducks at Akgöl, analysed using the method of Neu et al. *(1974). Distribution between zones was significantly different from random for Mallard (Anapl: χ^2 = 184, 3 df, $P < 0.0001$), Ferruginous Duck (χ^2 = 8.93, 2 df, $P < 0.02$), Marbled Teal excluding broods (Maran: χ^2 = 347, 4 df, $P < 0.0001$) and Marbled Teal broods (Brood: χ^2 = 1 818, 2 df, $P < 0.0001$).*

Species	Zone	PO	SI	CI on PO	CI on SI
Anapl	Mixed	0.954	1.59	0.927-0.981	1.54-1.63
	Scirpus[1]	0.007	0.02	0-0.017	0-0.05
	Pools	0.023	3.70	0.004-0.043	0.60-6.81
	Marsh	0.017	0.71	0.0001-0.033	0.005-1.41
Aytny	Mixed	0.790	1.31	0.674-0.905	1.12-1.50
	Scirpus	0.193	0.53	0.082-0.304	0.22-0.83
	Pools[1]	0.018	2.80	0-0.055	0-8.74
Maran	Mixed	0.545	0.91	0.422-0.669	0.70-1.11
	Scirpus	0.261	0.71	0.152-0.371	0.42-1.01
	Canal	0.068	32.1	0.006-0.131	2.63-61.5
	Pools	0.114	18.2	0.035-0.192	5.58-30.8
	Marsh[1]	0.011	0.49	0-0.038	0-1.61
Brood	Mixed[1]	0.222	0.37	0-0.517	0-0.86
	Scirpus[1]	0.111	0.30	0-0.334	0-0.91
	Canal[1]	0.667	314	0.332-1.0	156-470

PO = proportion of flocks observed.

SI = selection index (PO/PA from Table 2). Values > 1 indicate relative preference; < 1 relative avoidance; 0 zero use.

CI on PO = Confidence Interval on proportion of flocks observed (90% family confidence coefficient).

CI on SI = Confidence Interval on selection index (CI on PO/PA from Table 2).

[1] (PO × N) < 5, and confidence intervals may therefore be inaccurate (Neu *et al.*, 1974).

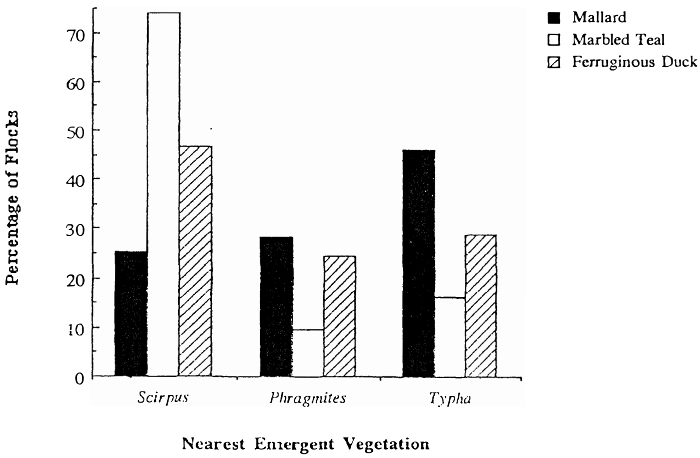
The result for broods remains significant when pooling canal and *Scirpus* zones so there are no expected values below 1 (χ^2 = 6.05, 1 *df*, $P < 0.02$).

= 5 m), Ferruginous Duck (0-150 m; median = 5 m) and Garganey (1-100 m; median = 20 m) (Fig. 4b). Differences between species were no longer significant when Garganey were excluded from the analysis (H = 5.42, 2 *df*, $P > 0.06$). Garganey used large, open spaces within the mixed emergent zone not used by the other species.

The distance to the lake fringe varied greatly between flocks of Mallard (0-1 000 m; median = 100 m), Marbled Teal (0-1 200 m; median = 150 m) and Ferruginous Duck (50-1 200 m; median = 500 m) (Fig. 5). Pairwise (Mann-Whitney) tests showed that Ferruginous Duck was significantly different to Mallard and Marbled Teal ($P < 0.0001$), but there was no difference between Mallard and Marbled Teal ($P > 0.6$).

When ducks in Lake Akgöl were observed on the water, rather than inside emergent vegetation, they were concentrated in dense beds of *Potamogeton pectinatus* (Table IV). Of ducks of all four species feeding in Akgöl, 91.0 %

a)



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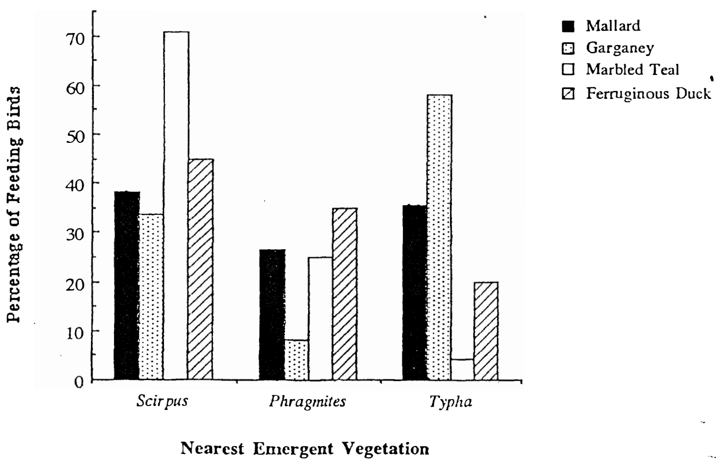

Figure 3. — a) Proportion of flocks of Mallard (N = 197), Marbled Teal (N = 62) and Ferruginous Duck (N = 45) recorded in Akgöl closest to *Scirpus litoralis*, *Phragmites australis* and *Typha* sp. Differences between species were highly significant ($\chi^2 = 49.93$, 4 *df*, $P < 0.0001$).

b) Proportion of individual feeding Mallard (N = 110), Garganey (N = 62), Marbled Teal (N = 24) and Ferruginous Duck (N = 40) recorded in Akgöl closest to *S. litoralis*, *P. australis* and *Typha* sp. Differences between species were highly significant ($\chi^2 = 33.59$, 6 *df*, $P < 0.0001$).

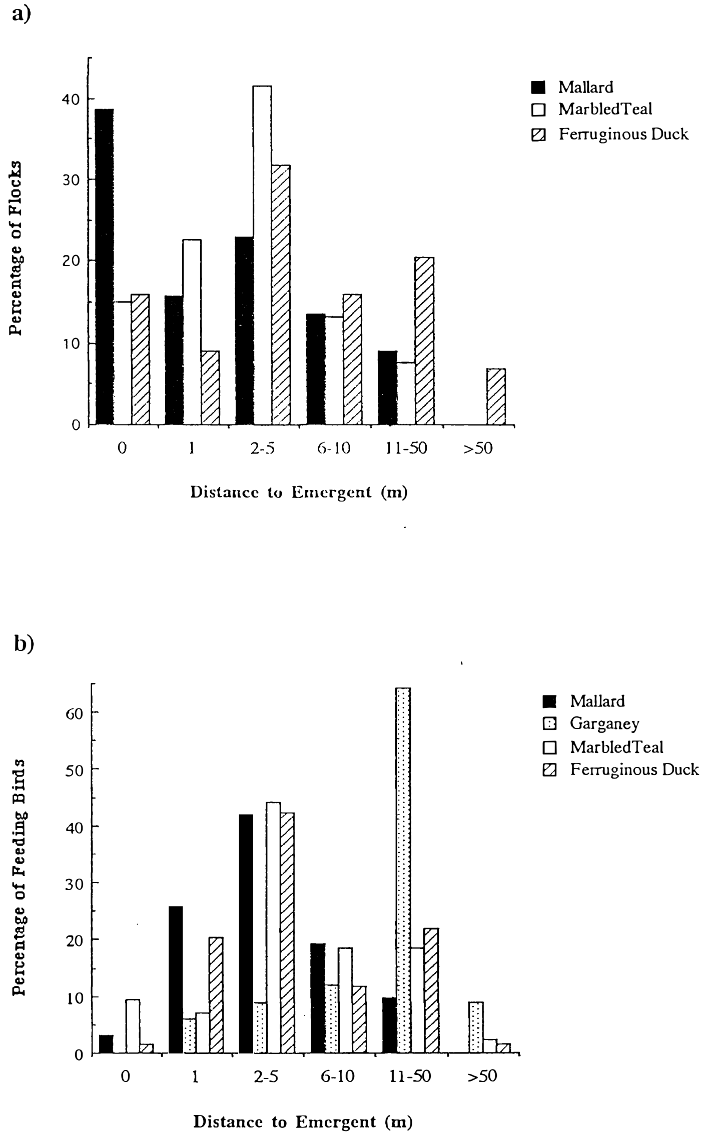

Figure 4. — a) Distribution of mean distances to nearest emergent vegetation (m) for flocks of Mallard (N = 178), Marbled Teal (N = 53) and Ferruginous Duck (N = 44) in Akgöl. Differences between species were highly significant (Kruskal-Wallis test, $H = 15.56$, 2 *df*, $P < 0.001$).

b) Distribution of distances to emergent vegetation (m) for individual feeding Mallard (N = 124), Garganey (N = 67), Marbled Teal (N = 43) and Ferruginous Duck (N = 59) in Akgöl. Differences between species were highly significant (Kruskal-Wallis test, $H = 78.11$, 3 *df*, $P < 0.001$).

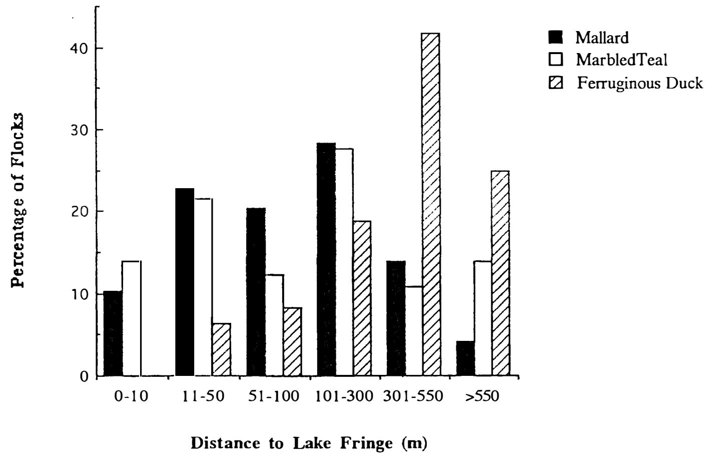

Figure 5. — Distribution of mean distances to lake fringe (m) for flocks of Mallard (N = 215), Marbled Teal (N = 65) and Ferruginous Duck (N = 48) in Akgöl. Differences between species were highly significant (Kruskal-Wallis test, $H = 39.05$, 2 *df*, $P < 0.001$).

TABLE IV

Number of individuals and flocks (in parentheses) of ducks in Lake Akgöl recorded in water with and without dense growths of Potamogeton pectinatus *in the surface layer.*

	Area (ha)	Anapl		Anaqu[1]	Maran		Aytny	
With	350	279	(124)	82	53	(24)	110	(36)
Without	800	8	(5)	4	16	(4)	13	(5)
Total	1,150	287	(129)	86	69	(28)	123	(41)

[1] not effectively divided into flocks. Anapl = Mallard. Anaqu = Garganey. Maran = Marbled Teal. Aytny = Ferruginous Duck. Figures include ducklings. All species show highly significant selection for areas with *P. pectinatus* (χ^2 tests, $P < 0.0001$).

(N = 299) were feeding where a dense bed of *P. pectinatus* filled the surface layer. This proportion was significantly lower in birds that were diving (70.0 %, N = 50) than those feeding by other methods (95.1 %, N = 246; $\chi^2 = 31.6$, 1 *df*, $P < 0.0001$). When diving birds were excluded, there were no differences between duck species ($\chi^2 = 1.58$, 3 *df*, $P > 0.8$) or between feeding methods ($\chi^2 = 2.64$, 4 *df*, $P > 0.5$) in the frequencies of *P. pectinatus* in the surface layer. All feeding in locations without *P. pectinatus* in the surface layer was observed where dense beds of this species, *P. panormitanus* or *Chara vulgaris vars.* were present below the surface.

DISCUSSION

Habitat selection is a hierarchical process (Johnson, 1980), and I have found non-random selection by ducks at various levels in the Göksu Delta. I can only draw conclusions about daylight hours, and habitat use can be very different at night (see McNeil *et al.*, 1992 for review). Furthermore, I have studied only a small part of the year, and habitat use by ducks varies at different times of the annual cycle (Amat, 1984; Batt *et al.*, 1992; Nummi & Pöysä, 1993).

SELECTION OF WETLANDS

The concentration of all duck species at well vegetated, brackish lakes and their avoidance of saline lakes and drainage canals was probably a consequence of their requirements for extensive, well-vegetated and highly productive wetlands in the breeding and post-breeding periods (Batt *et al.*, 1992; Elmberg *et al.*, 1993). Emergent vegetation provides shelter to the ducks and to invertebrates (Voigts, 1976; Nummi & Pöysä, 1993). Submerged vegetation provides a home for invertebrates and is a major duck food itself (Krull, 1970; Anderson & Low, 1976; Voigts, 1976; Godin & Joyner, 1981).

Although high salinities can affect the health of ducks (Swanson *et al.*, 1984; Moorman *et al.*, 1991), Paradeniz and Kugu Gölü were probably not avoided because of their relatively high salinities *per se*, but rather due to their lack of extensive vegetation, as suggested by the avoidance of the exposed, open part of Akgöl. Pöysä (1983a) observed a similar avoidance of the open parts of a lake in Finland by dabbling ducks, and attributed it to the high wave action and predation risk in these areas. In Spain, Marbled Teal breed in saline wetlands provided they offer extensive areas of emergent vegetation (Navarro & Robledano, 1995). In contrast to the present study, Paradeniz holds major concentrations of ducks during winter (DHKD, 1992).

The avoidance of drainage canals away from the vicinity of Akgöl was probably caused by their narrow width, steep sides (up to 3 m) and exposed position in an agricultural landscape. Decreasing wetland size and increasing isolation from other wetlands cause a decrease in the richness of duck and other waterbird species (Brown & Dinsmore, 1986; Nudds, 1992; Elmberg *et al.*, 1994).

SELECTION OF BIOTOPES

Whereas little partition of duck species was observed between different wetlands, there was marked horizontal partition between different biotopes at Lake Akgöl. There may be biases in these studies, since the censuses were not perfect and birds are most likely to have been overlooked in the mixed emergent zone and least likely to have been overlooked in the relatively open pools and marsh zones. However, these problems were not large enough to bring into question the main conclusions, because the differences in usage of zones and between duck species were marked, duck distribution was similar in each of the three complete censuses of Akgöl and biases were similar for each species. The most likely consequence of these biases is that the importance of the mixed emergent zone was underestimated for all species.

The differences in biotope selection between duck species were related to differences in foraging ecology (Green, 1998b). Mallard specialized in feeding towards the bottom of the water column and avoided the offshore areas of Akgöl which were deeper than the 43 cm accessible to an up-ending Mallard (Godin & Joyner, 1981). Water depth was not so limiting to Marbled Teal, which fed near the surface, or to Ferruginous Duck which fed mainly by diving (Green, 1998b). The *Scirpus*-only zone may have been more important to Marbled Teal because *S. litoralis* seeds were an important part of their diet (Green & Selva, unpubl.). Garganey probably fed mainly on *Potamogeton pectinatus* (Green, 1998b), which was more readily available in the mixed zone.

Marbled Teal and Mallard showed a relative preference for shallow pools, despite disturbance from humans walking around the lake. This may be due to relatively good foraging conditions. At shallow depths where Marbled Teal fed, the pools offered higher densities of seeds and insects than Lake Akgöl (Green & Selva, unpubl.).

Habitat selection by Marbled Teal broods was different to that by mature Marbled Teal, as found in other duck species (Godin & Joyner, 1981; Mulhern *et al.*, 1985; Nummi & Pöysä, 1993, 1995) and explained by differences in foraging requirements, predation risk, etc. (Batt *et al.*, 1992). The canal zone entering Akgöl was so important for Marbled Teal broods perhaps because deep channels with well vegetated banks alongside extensive, shallow wetlands provide good conditions for brood rearing. This stretch of canal lay adjacent to an extensive, shallow marsh (Green, 1996a) and broods may have been feeding nocturnally in this exposed area and spending the day in the canal where they were safer from predators, although this requires further study. Similarly, in Spain, Marbled Teal broods are often seen in canals adjacent to ricefields or in deeper channels within natural marshes (Navarro & Robledano, 1995).

SELECTION OF MICROHABITATS

Within Lake Akgöl, association with *Phragmites* indicates the use of more luxuriant, inshore microhabitats, association with *S. litoralis* indicates the use of less luxuriant, offshore microhabitats and association with *Typha* is intermediate. Thus, association with emergent vegetation suggests that Marbled Teal used less luxuriant microhabitats than Ferruginous Duck and Mallard. However, distance to the lake fringe showed that Ferruginous Duck used more offshore microhabitats than Marbled Teal and Mallard. This is perhaps associated with the more completely aquatic habits of Ferruginous Duck, which, unlike the other species, never roosted out of the water around the edge of the lake. These somewhat contradictory results reflect the complexity of the aquatic environment, and illustrate the importance of considering as many variables as possible when comparing the microhabitat selection of different duck species (see Nudds *et al.*, 1994; Pöysä *et al.*, 1996).

That Mallards were positioned closer to emergent vegetation than Marbled Teal and Ferruginous Duck was explained by differences in diurnal activity. Mallards spent roughly half as much time feeding as Marbled Teal and Ferruginous Duck, spending more time roosting within or alongside emergents (Green, 1996b). Distances to emergents for feeding birds were much greater for Garganey. This was associated with their gregarious behaviour, moving around in large flocks and feeding in open locations where the whole flock could remain in visual contact. Garganey showed a strong preference for more open areas within the mixed emergent zone, relatively far away from the lake edge and bordered mainly by *Typha*.

All species showed a strong selection for beds of *Potamogeton pectinatus*, because of their importance as foraging habitat. This plant and the invertebrates that live on it are major foods for many duck species (Krull, 1970; Anderson & Lows, 1976; Sondergaard *et al.*, 1996; Green & Selva, unpubl.).

Pöysä (1983a,b) found that breeding Garganey were confined to shallow lake edges adjacent to emergent vegetation, perhaps because they could only reach submerged vegetation in the shallowest areas along the lake edge (unlike at Akgöl). Nudds *et al.* (1994) found that breeding Garganey were associated with more open, offshore microhabitats than any other dabbling duck apart from Shoveller *A. clypeata*. This contrasts with the findings of Pöysä (1983a,b) but is consistent with the current study. Given the ability of larger dabbling ducks to feed at greater depths in the water column, differences between sites in depth profiles and in the position of food in the water column can translate into major differences in the horizontal partitioning of species. Thus, in contrast to the current study, Pöysä (1983a,b) found that Mallards made more use of central, open areas than Garganey owing to the ability of Mallard to feed in deeper areas.

As in the current study, several previous studies have found Mallard to be strongly associated with shoreline vegetation (Pöysä, 1986; Monda & Ratti, 1988; Nummi *et al.*, 1994). It is noteworthy that the rare and threatened Marbled Teal used a broader range of biotopes (i.e. had a wider niche) than the abundant and apparently more adaptable Mallard. As can be expected for a diving duck, the threatened Ferruginous Duck made less use of shallow, peripheral habitats, but was less specialized than Mallard in its use of biotopes in Akgöl. Similarly, Monda & Ratti (1988) found Mallard to be the most specialized species in a community of breeding dabbling ducks. It seems that the Mallard is a generalist in its geographical distribution, and ability to exploit a wide range of wetland types (Cramp & Simmons, 1977; Amat & Ferrer, 1988), but is often a specialist in its microhabitat use within a given environment.

Nudds *et al.* (1994) suggested that dabbling ducks with finer lamellae tend to use more open, deeper microhabitats further offshore because of the size distribution of invertebrate food (but see Pöysä *et al.*, 1996). Of the three dabbling ducks studied here (Marbled Teal is a dabbling duck in ecological but not taxonomic terms [Livezey, 1996; Green, 1998b]), Mallard have the broadest lamellae and Marbled Teal the finest (Pöysä, 1983a; Green, unpubl.). Thus, the microhabitat selection recorded in the current study is consistent with the hypothesis of Nudds *et al.*

IMPLICATIONS FOR CONSERVATION

This is the first detailed study of habitat selection by Marbled Teal and Ferruginous Duck, and confirms anecdotal reports that these species are highly dependent on luxuriant wetlands (Cramp & Simmons, 1977; Green, 1993, 1995; Navarro & Robledano, 1995). This study has important implications for the conservation of Marbled Teal and Ferruginous Duck which are undergoing population declines in the Mediterranean region largely due to the loss of breeding habitat (Green, 1993; Tucker & Heath, 1994; Heredia *et al.*, 1996). Many breeding sites have been destroyed and others have suffered a loss of vegetation owing to factors such as sedimentation, salinisation, reduced duration of flooding owing to water extraction and dam construction in the catchment, overgrazing and the introduction of exotic species (Green 1993; Tucker & Heath, 1994; Navarro & Robledano, 1995; Heredia *et al.*, 1996; Callaghan, in press).

The recovery of the Marbled Teal and Ferruginous Duck requires the reestablishment of extensive, densely vegetated habitats similar to those at Akgöl. Shallower habitats 5-20 cm deep (e.g. pools surrounding Akgöl) are of more value to Marbled Teal, whereas Ferruginous Duck feed mainly in areas 30-60 cm deep (Green, 1998b; Green, unpubl.). Although Marbled Teal are adapted to exploit temporary Mediterranean wetlands (Green, 1998a), both species are clearly able to exploit artificial, permanent wetlands such as Akgöl. The current study provides little evidence that the rarity and restricted distribution of these ducks in the Mediterranean is connected with specialized microhabitat requirements. Although Garganey are widely dispersed and exploit small wetlands when breeding (Cramp & Simmons, 1977; Hagemeijer & Blair, 1997), on post-breeding passage they appear to require open spaces capable of supporting large flocks within relatively large, luxuriant wetlands. They appear to be dependent on a small number of suitably large passage sites, whose effective protection is essential to prevent population declines (Tucker & Heath, 1994; Scott & Rose, 1996).

Akgöl is undergoing rapid succession as a result of the input of nutrients and sediments from agricultural areas (DHKD, 1992). Lake depth is decreasing, and the proportion of its surface covered by emergent vegetation is increasing. Waterbird diversity is maximized at intermediate stages of succession when there is a greater diversity of emergent species (Danell & Sjöberg, 1978; Nudds, 1992; Elmberg *et al.*, 1993, 1994). Without intervention, Akgöl will eventually turn into a huge *Phragmites* bed of little value to ducks. Beforehand, there will be a gradual decrease in the coverage of *S. litoralis* and increase in the coverage of *Typha* and *Phragmites* which seems likely to reduce the value of Akgöl for Marbled Teal more quickly than for Mallard. The increasing loss of open spaces between emergent beds will be detrimental to Garganey.

Another cause for concern is the future of submergent vegetation in Akgöl, the loss of which may devastate the duck populations. Dense beds in the surface layer allow Marbled Teal and other dabbling ducks to feed in areas up to 70 cm deep (Green, 1998b), where they would not be able to reach the sediments that provide an alternative feeding medium. Shallow, eutrophic lakes such as Akgöl may have two alternative equilibria, and a switch from the current "clear water" state dominated by macrophytes to a "turbid water" state dominated by phytoplankton could occur in the future, prompted by a further increase in the nutrient levels in the lake, an increase in fish density or other perturbations (Scheffer *et al.*, 1993). It is extremely important that such a switch to a "turbid state" at Akgöl be prevented and that the proposed introduction of grass carp *Ctenopharyngodon idella* to the Göksu delta is prevented (Crivelli & Rosecchi, 1992).

Shallow sites around the periphery of Akgöl (the canal and pool zones) have a disproportionate importance for Marbled Teal, and should be carefully protected and managed. Reed-cutting in the canal should be restricted so to maintain and improve the emergent fringe along the banks and should be confined to the non-breeding season. The creation of more pools around the lake should be considered and would also benefit waders and herons, which are highly dependent on these shallow, open habitats within the delta (pers. obs.). Further research is required to clarify the ecological requirements of Marbled Teal and Ferruginous Duck at other times of the year.

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SUMMARY

Diurnal habitat selection of the Marbled Teal *Marmaronetta angustirostris*, Ferruginous Duck *Aythya nyroca*, Garganey *Anas querquedula* and Mallard *A. platyrhynchos* were studied in the Göksu Delta, Turkey from 10 July to 6 August 1995. This is the first detailed study of habitat use by the globally threatened Marbled Teal and Ferruginous Duck. All species were concentrated in lakes with dense beds of emergent and submerged vegetation, avoiding open and saline lakes and narrow, isolated canals. Garganey and Mallard were concentrated in the "mixed emergent zone" of brackish Lake Akgöl, which held a mixture of *Phragmites australis*, *Typha* and *Scirpus litoralis*. Marbled Teal made most use of a more central zone containing monospecific stands of *S. litoralis*, whilst Ferruginous Duck were intermediate. Mallard and particularly Marbled Teal showed a relative preference for small pools around the edge of the lake, which were shallower and probably permitted a higher foraging intake. Marbled Teal broods were highly concentrated at the influx of a drainage canal into the lake, which provided a safe diurnal refuge adjacent to possible nocturnal feeding habitat. Within Lake Akgöl, Marbled Teal used microhabitats dominated by *S. litoralis*, Garganey were most associated with *Typha*, whereas Mallard and Ferruginous Duck were evenly associated with these species and with *Phragmites*. Mallard remained closest to emergent vegetation, and Garganey made most use of open microhabitats away from emergents. Ferruginous Duck used areas farthest away from the lake edge. All species showed strong selection for dense beds of *Potamogeton pectinatus*, owing to their importance as foraging habitat. Careful management is required to maintain Akgöl's high value for waterbirds. The recovery of Marbled Teal and Ferruginous Duck populations in other parts of the Mediterranean requires the conservation and restoration of breeding sites with luxuriant vegetation.

RÉSUMÉ

La sélection de l'habitat diurne a été étudiée du 10 juillet au 6 août 1995 dans le delta de Göksu, Turquie, pour la Sarcelle marbrée *Marmaronetta angustirostris*,

le Fuligule nyroca *Aythya nyroca*, la Sarcelle d'été *Anas querquedula* et le Canard colvert *Anas platyrhynchos*. Il s'agit de la première étude détaillée de ce type pour les espèces globalement menacées que sont la Sarcelle marbrée et le Fuligule nyroca. Toutes les espèces étaient concentrées sur des lacs riches en denses formations végétales émergentes ou sub-émergentes, évitant les lacs ouverts et salés ainsi que les canaux étroits et isolés. La Sarcelle d'été et le Colvert étaient concentrés dans la « zone émergente mixte » du lac Akgöl, saumâtre, composée d'un mélange de *Phragmites australis*, *Typha* et *Scirpus littoralis*. La Sarcelle marbrée se localisait essentiellement dans une zone plus centrale, pourvue de formations monospécifiques de *S. littoralis*, le Nyroca étant intermédiaire. Le Colvert et en particulier la Sarcelle marbrée montraient une certaine préférence pour les petits étangs autour du lac, moins profonds et qui permettaient probablement une meilleure alimentation. Les nichées de Sarcelle marbrée étaient très concentrées au debouché d'un canal de drainage dans le lac, ce qui constituait un refuge diurne sûr, adjacent à un gagnage nocturne possible. Sur le lac Akgöl, la Sarcelle marbrée utilisait des microhabitats dominés par *S. littoralis*, la Sarcelle d'été était davantage associée aux *Typha* tandis que le Colvert et le Nyroca étaient autant associés aux *Typha* qu'aux *Phragmites*. Le Colvert restait au plus près de la végétation émergente, la Sarcelle d'été utilisant surtout les microhabitats ouverts loin des émergents. Le Nyroca utilisait des zones au plus loin de la rive du lac. Toutes les espèces sélectionnaient fortement les denses formations de *Potamogeton pectinatus*, en raison de leur importance en tant qu'habitat d'alimentation. Une gestion prudente est requise pour maintenir la forte valeur d'Akgöl pour les oiseaux d'eau. Le rétablissement des populations de Sarcelle marbrée et de Nyroca dans d'autres parties de la region méditerranéenne nécessite la conservation et la restauration de lieux de reproduction à végétation luxuriante.

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